THE LIFE HISTORY OF A RIVER.

By ERASMUS HAWORTH, University of Kansas, Lawrence.

Presidential address, delivered before the Kansas Academy of Science, at Topeka, Kan., January 1, 1909.

DURING recent times much interest has been manifested in river floods and how to prevent damages from the same. This is particularly true in eastern Kansas and southwestern Missouri; a district with an annual rainfall of from forty to forty-five inches; a district with drainage streams which long ago reached the condition of grade or base level, and have since widened their channels to extraordinary widths with the usual meanderings by which the actual lengths of the channels have been increased many fold; a district subject to exceedingly irregular precipitation, and one therefore which is liable to have a period of floods at any time in the year or to have none at all. Elsewhere in America a like interest is manifested, partly due to increasing damages from floods as a necessary result of increase in population and improvements, but largely due to the general tendency of federal and state governments to look into matters of general public interest, and where deemed possible to give aid for a betterment of conditions.

This last aspect of the subject is modern—scarcely more than a decade old in most states—and, as a result, little has yet been accomplished beyond preliminary investigations and preliminary discussions of methods to be executed later. Practically all the states in the Mississippi valley have taken up the matter in one way or another, so that we now find measures enacted into law on the statute-books of the several states. Such statutes, although varying greatly in detail, are fairly uniform in one respect, namely, the creation by law of certain drainage districts with power to assess taxes on real estate for the purpose of making such improvements as each individual district may deem advisable. The federal government likewise has at least two departments—the Department of Agriculture and the United States Geological Survey—each of which is giving attention to the subject and for which limited appropriations have been made by the Congress of the United States. In each instance investigations of flood conditions are, in a measure, entwined with those of reclaiming swamp-lands and marshes.

Up to the present time the United States Geological Survey has done nothing in this line in Kansas. The Agricultural Depart-

ment, however, has made some preliminary surveys in the valley of the Neosho river, with a desire to ascertain what could be done to prevent such vast destruction of property by floods of that stream. Our neighboring state, Missouri, by proper legislation has legalized the drainage district idea, and in one notable case a comparatively large district has been organized and work is well under way whereby vast sums of money will be expended and a most interesting experiment undertaken. I refer to the work now in progress of straightening the channel of the Marias des Cygnes river in the southwestern part of Bates county, near Rich Hill.

Since the unusually high and destructive floods of 1903 different railroad companies have attempted to guard against further damage by building their grades excessively high across river vallies. This is notably true with the Santa Fé line across the Wakarusa valley south of Lawrence and across the Verdigris river valley just east of Independence, Kan. The present conditions in the Kansas river valley in the vicinity of Kansas City likewise should be mentioned in this connection. Where the various railroad lines cross and recross the valley in many different ways, apparently the management for each line has attempted to lift his grade as high as possible, with a hope of keeping the track above the water level in times of great floods. Years ago a similar attempt was made by the Missouri Pacific and other railroad companies whose lines cross the Marais des Cygnes river valley in the vicinity of Pleasanton and La Cygne, Kan., and eastward towards the Missouri state line.

At the present time there seems to be a prevailing idea that local, sometimes exceedingly local, improvements or precautions can be taken which, when properly executed, will protect a local area against flood damages regardless of what is done elsewhere in a given river valley. This is notably true along the Kansas river. Under the state law created by the state legislature called in extraordinary session in the summer of 1903, immediately after the destructive flood of that summer, drainage districts have been organized and much agitation has resulted regarding what to do and how to do it. There seems to be a general sentiment of widespread extent that all any local area need to do is to organize a drainage district according to law obtain the assistance of an engineer, and in a comparatively easy and simple way protect themselves against all future flood devastation.

It has seemed to the writer throughout this whole period of agitation that in most instances the proposed improvements for protection when executed may be almost futile and fall far short of

expectation. In some instances such improvements when made in a large measure will be directly in opposition to the great laws of nature which govern rivers. So few people apparently understand the foundation principles of rivers that, after all, mistakes of the kind above alluded to need not be surprising. It is desired, therefore, in the short time allotted to this paper to point out a few of the principles of nature governing rivers, to show the shortcomings of some of the schemes already adopted and of others proposed for adoption in various places, and possibly to make a few suggestions which may be of assistance to those engaged in this exceedingly important undertaking. The great fundamental laws of river erosion and river processes are plain and simple and easy to understand. Probably on account of their simplicity many people have failed to understand them or to believe in them when pointed out, insisting, as seems to be the part of human nature, that such processes must be more complicated and more mysterious.

It is only within the last half century, so far as I can learn from history, that any one has fully comprehended the principles governing the life history of a river. I need only refer to the well-known fact that when Captain Eads first proposed the improvements at the mouth of the Mississippi river, commonly known as "Eads' Jetties," it took him years to persuade our national legislators that such a scheme would accomplish the desired results, even if properly executed. It is an interesting fact of history that practically all the great engineers of our nation scoffed at the idea and insisted that his scheme was utterly impracticable, and, therefore, should not be attempted. And to-day I may say—and I do it in a spirit of humility and not one of criticism—and to-day I may say it is one of the greatest surprises to find how large a proportion of the practical engineers of our country have failed to grasp the fundamental principles of river action and put into execution improvements and precautions based upon them.

RIVER PROCESSES.

Every stream of water, no matter where situated on the surface of the earth, obeys the same fundamental laws that govern every other stream. It matters not where one goes to study this subject, data can be gathered in all parts of the world. Let us suppose that we are studying a stream in a mountainous district where the inclination of the surface is comparatively great, say at least 100 feet to the mile. During rainy weather the stream in question will have a fair amount of water and the tendency will be for it to cut its channel deeper. The cutting process is carried on in part

by the chemical action of the atmosphere, in part by the mechanical action of the flowing water. It matters not what the agencies are in detail, the point is that it cuts its channel deeper. This deepening of the channel will be continued until by and by a condition will be reached which prevents the deepening process being carried any further until general environments are changed. To give all the details substantiating this would require too great a time, but they are connected principally with the law governing the carrying power of flowing water. The carrying capacity of moving water varies as the sixth power of the velocity. Suppose, for instance, we have a stream with its water moving one mile an hour, and a second stream with its water moving two miles an hour. The carrying capacity of the water in the second stream will be sixty-four times as great as the water in the first stream. It is difficult for one to believe that this statement is true, and yet it is true both in theory and in practice, and has been incorporated in our standard text-books for twenty-five years or more.

Our stream under consideration during ordinary times will have but a small amount of water in it, and that will move at a slow pace, and will have but little carrying capacity. Its work in deepening the channel will consist principally in the dissolving power of the water. But when the heavy rains come and ten, twenty, and a hundred times the amount of water is poured into the channel the velocity of the moving water is greatly increased, and the carrying power correspondingly increased according to the ratio above named. The energy of this moving water will be devoted principally to cutting its channel deeper, until the water has all the load it can carry. In order to deepen its channel more, therefore, it must be given a greater velocity, or in some way it must get rid of some of its load.

Suppose now that at some place along the channel the velocity should be checked, never so little possibly. With a decrease in velocity the carrying power will be decreased sixty-four times as much. If the water was loaded to its limit a part of that load will be deposited the very instant a perceptible checking of the velocity is brought about. At that instant, therefore, the water ceases to cut its channel deeper and the reverse process is begun — that of filling up the channel. Usually the decrease in velocity is at or near the mouth of the stream, so that the filling up process begins at the mouth. It is common, therefore, to find a stream which is still cutting its channel deeper in its upper parts and the same stream filling up its channel in the lower part of its course.

If now we have a stream that rises in a mountainous district and flows across a plains area, and untimately enters the ocean, we have such a variety of surface inclinations that complications are set up. When the terrific rains come in the mountains the streams with high declivity assume the proportions of mountain torrents and the carrying power of the water becomes so enormously great that mud and silt and sand, gravel and boulders, all together are hurled downward as though they were mere toys. Few can appreciate the limit of such power. I have seen boulders, egg-shaped in proportion, more than twenty feet in diameter, weighing doubtless more than a hundred tons, which have been carried along by these mountain torrents; and as they went bumping the bottoms and the sides of the channel they produced wonderful execution. The same stream of water, however, cannot have this high velocity forever, and as the plains region is reached the angle of declivity is reduced, the velocity correspondingly is retarded, the carrying power is much more reduced and the unloading process is necessary. The first objects to be unloaded, of course, will be the largest ones. The force of the water against a boulder, or a gravel, or a grain of sand, is proportional to one-half the surface of the object, which, in turn, is proportional to the square of the diameter, while the weight is proportional to the volume, and that in turn proportional to the cube of the diameter. Therefore, the largest objects will be dropped first.

Visit a mountain stream whenever you may and you will find the boulders accumulating where the first check in the velocity of the current was brought about. If the decrease in velocity is sufficiently great, sand and mud will be intermingled with the boulders, but if the decrease is limited, then we find the boulders washed clean, the finer particles having been carried farther along. I need only revert to such streams as the Rio Grande, rising in the mountains above Albuquerque; the Arkansas, rising in the vicinity of Cripple Creek; the Potomac, rising on the summit of the Appalachians, or any one of the many other streams known to all. Where the angle in the surface is greatest there the most unloading occurs.

This unloading sometimes reaches enormous proportions, and the river builds up its channel until in extreme cases it is hundreds of feet above the plains on either side. Of course, such conditions cannot exist long, and sooner or later the water of the river will overflow its bounds and will get down onto the lower grounds on the right hand or the left, only to build up another channel. In

this way a stream from a high mountainous area crossing a wide plain may have migrated over hundreds of miles laterally. Excellent examples of this may be observed at the present time in streams reaching the Pacific coast from the Coast Range mountains. It is universally true that the streams in the steeper parts are still cutting their channels deeper, while on the plains between the mountains and the ocean they are building up their channels with debris brought from above, and are shifting from place to place as above mentioned. The question, therefore, of whether or not a stream will cut its channel deeper or will fill up the channel and elevate itself to positions actually farther from the center of the earth than those previously occupied is dependent entirely upon the somewhat intricate and delicate balancing of velocities and loads.

FLOOD-PLAINS.

The building-up process at the bottom of the river channel and the widening of the bluff lines soon produce an almost level valley area known as the flood-plain. In times of high water a river covers the entire flood-plain and a variable amount of sand and silt and mud are deposited, thereby building up the general level of the valley. Some streams have built up their flood-plains for more than 100 feet, as shown by the depth of the flood-plain material. In general, the depth is greater near the mouth of a stream, but irregularities of surface produce great irregularities in the thickness of the flood-plain material throughout a flood-plain area. The materials usually are laid down in broad, horizontal layers well stratified, but sometimes local irregularities occur where washouts, sink-holes, etc., are made in the flood-plain material during times of high water.

It should be noted that the very presence of a river flood-plain is evidence that the river has covered the entire flood-plain area. Earth movements often change such conditions, allowing a stream to begin cutting its channel anew after it has built up a former flood-plain. Such cases are rare in the Mississippi valley, however, and in eastern Kansas none have been found. The highest ground existing in any of the eastern Kansas river valley flood-plains was created by flood waters from the stream and remain to-day a silent witness to the fact of great floods having overflowed the entire flood-plain area, no matter what the stream may be.

We may say, therefore, in discussing any particular part of a stream, that in its early stages, in its youthfulness, it is deepening its channel, but when the period of maturity has been reached it

is no longer capable of cutting its channel deeper. Water continues flowing through it, however, and a process of meandering is as absolutely necessary as it is that the stream exist. This meandering of the channel is a most important point, particularly in connection with all river improvements. As cutting continues under this new set of conditions, the so-called ox-bow curves are formed, such as can be seen along the course of any stream.

Let us suppose that we could straighten the channel of a stream throughout a distance of a hundred miles, building an entirely new channel. Would this new channel remain straight for any considerable length of time? It certainly would not unless extra precautions were used. If the water be encased in walls of masonry, the channel would remain straight as long as the masonry walls remained intact. If a less pretentious protection were given and the walls were riprapped, using the term in the ordinary way, meandering processes would be hindered, but sooner or later the tendency would become so great that the riprapping would be worn away in places, after which its existence elsewhere would only assist and intensify meandering processes. This same fact may be stated in another way. Any channel of a river may be kept in its present position by a sufficient interference on the part of man so long as this interference is maintained. If the people in a given community wished to retain a river channel in its present position for a thousand years, they could do so by a sufficiently strenuous effort in the way of preventing the stream from cutting its banks. The converse of this is also true. A stream which has already ceased cutting its channel deeper may be made to shift its channel at the will of man, provided sufficient influence is brought to bear upon it, the energy of the running water being used entirely for the execution.

When a stream has reached a certain degree of meandering or of crookedness, the same stream has a tendency to straighten its own channel. This tendency is manifested principally in two ways, one by cutting its banks during mild floods until the necks of the ox-bow curves are destroyed; the other by excessive floods when the water spreads from bluff to bluff and the current, ignoring the ordinary channel, flows in an approximately straight line between the bluffs. This new current often cuts a new channel deep enough to hold the current after the flood has subsided. A river, therefore, makes crooked its own channel, apparently in order to have the privilege of straightening it, but in reality when working under the inflexible laws of nature.

APPLICATION.

To apply the general principles already enumerated and to bring about by a variety of coercion a set of conditions which will in a measure decrease the extent of floods, and thereby lessen the destruction of life and property in the river valleys during flood periods, is the end sought by all investigations and all improvements undertaken, as outlined earlier in this paper. The end sought by different parties is the same, and there should be a unanimity and coöperation in our efforts.

Floods are caused primarily by excessive and irregular rainfall, a statement so simple that few people realize its importance. Were our annual precipitation uniform week by week and month by month the river channels now on the face of the earth probably are abundantly large to carry all the precipitation back to the ocean without overflowing the banks of a single stream. But rainfall is most irregular, and combinations of this irregularity are almost infinitely variable. Could our heavy rains come all at once over the entire drainage area of a stream so that they would produce the maximum effect our floods would be many times more disastrous than they are. For example, throughout the Mississippi valley, it is by no means unusual for as much as four inches of rain to fall within a period of forty-eight hours and in many places a rain of two or three inches sometimes falls within a period of one hour. Who can calculate the results should we have a precipitation of four inches throughout the entire Mississippi river drainage area within the same period of forty-eight hours? The floods would so far exceed anything that has ever been known by man that we can hardly conceive of the disaster which would follow. But, fortunately for mankind, the rainfalls are irregular, and during the short period of the white man's inhabitance of the Mississippi valley no instance has been known when all of the great tributaries of the Mississippi river were at their highest flood at the same time.

Instead of four inches of rain, sometimes we have six, or eight, or ten, or even more, over small areas within a very short time. One extreme case came under my observation during the past summer. A relatively small area in northeastern Kansas lying north of the Kansas river and principally east of the Blue river received a total precipitation of forty-five inches within a period of five months, nearly all of which came within two months, and in some instances from four to six inches came within as many hours. The little town of Frankfort, in Marshall county, is situated on a small stream, less than two miles from its source, and the thought of danger from

floods apparently never occurred to its citizens when the town was first located. But during the early summer of 1908 one of those terrific rainstorms came which covered the whole surface with from four to six inches of water and the little stream was utterly incapable of carrying water away as fast as it should have done. As a result, the streets of Frankfort were flooded, parts of the village which presumably were on high ground were inundated, and even a passing freight-train carrying live stock was stranded and the live stock drowned while the cars were standing on the track.

It is a combination of such extreme cases of rainfall that produces our floods. If they have occurred in the past they may occur in the future, and no matter what the improvement may be, or how many drainage districts with corporate power may be called into existence, now and then as time progresses these unfavorable combinations will occur and flood conditions will exist far beyond the control of man. So long as we are unable to control the rainfall and compel it to come somewhat at our pleasure just that long floods will come, river valleys will be covered with water, property will be destroyed and human lives lost. Unfortunately, science has not yet discovered the fundamental principles of meteorology. No basic principles are known upon which may rest long-range predictions of rainfall. We do not know whether next year will be wet or dry, and if wet, whether excessively so. We cannot foretell whether the heavy rains will come all at once over wide areas, causing the most disastrous floods of history, or very irregularly, so that but slight damage will be done. One thing is sure, namely, wherever a river flood-plain now exists it has been covered with water from that stream. If so in the past, why not in the future, and why not have a greater combination of heavy rains than ever before and a greater flood than ever before? So long as we remain in such gross ignorance concerning the profound laws of meteorology just that long will we be in like ignorance regarding the probabilities of unfavorable combinations which produce destructive floods.

It seems most improbable that climatic conditions have changed to any considerable degree in recent times, or that they will change within the next thousand years sufficiently to have much influence on floods; and even should they change, the new conditions are just as liable to be worse as to be better. It is the duty of the scientist, therefore, to look at matters just as they are. From this standpoint it seems practically certain that occasionally excessive floods will come which will be so great that any and all the works

of man will be powerless in the prevention of great disaster. Such an agent of destruction should be looked upon in a measure as we look upon earthquakes and tornadoes and volcanoes—nature's great processes for modifying and beautifying the surface of the earth—and man should avoid their disastrous results principally by keeping out of their way. It should not be considered a mark of the highest degree of intelligence deliberately to put one's self directly in the pathway of such a manifestation of nature's forces.

The above general statements refer to major or excessive floods. A great many minor floods occur which are less destructive in their action, and which, in a measure, certainly may be modified and made less severe. Three different lines of improvements or methods have been suggested, commonly called the reservoir method, the levee method, and the channel-straightening method. These may be considered separately.

RESERVOIRS.

Flood prevention by the reservoir method is believed in by those who consider it feasible to build many reservoirs throughout the drainage area of a stream so that a portion of the rainfall water may be caught in the reservoir and doled out leisurely to the streams under the control of man. It is argued that it is the last portions of the rainfall added to rivers which cause the floods, and that therefore such portions as may be held in the reservoirs will in a degree keep the "last portions" from entering the stream and thereby prevent the flood. But the facts are that such reservoirs are filled with the first part of the rainfall and not with the last part, and the water caught in them, if let alone, would be the first to enter the streams, and probably would be well out of the way down-stream before the last came. Could we build reservoirs with draw-gates so that we might let the first storm water run through them and then close the gates and hold the last rainfall they would undoubtedly be of service.

In the arid and semiarid districts, where the rainfall is under twenty inches per annum, some of the most severe local rain-storms occur. The ground is usually dry and hard and parched, and the rain-storms are so excessive that a large proportion of the total rainfall runs off the surface and down into the streams, causing excessive local floods. In such regions reservoirs would be most serviceable, because they could be built so as to hold a larger fraction of the rainfall, and in a degree would compensate for the excessive rapidity of precipitation. In a climate such as is general throughout the Mississippi valley, however, it is doubtful about

the reservoir system exerting a very appreciable effect. The tendency, however, would be in the right direction and we should combine all methods which have the proper tendency, in order that in the end we may have the greatest influence.

FORESTS.

During recent years much has been said regarding the influence which deforesting and reforesting an area may have upon floods. The great champion in the cause of cultivating forests to prevent damage by floods is the honorable Government Forester. His enthusiasm has become contagious, and advocates of reforesting treeless areas as a means of flood prevention are numerous in all parts of the United States. The subject is discussed here because in a way it corresponds to the reservoir system.

Rain falling upon a forested area is partially consumed in wetting the leaves and branches of the trees, and to a perceptible degree the water is held back and enters the drainage channel more slowly, which in turn prevents a sudden rise of the stream. For ordinary rains and mild floods there can be no doubt but that such a covering of forest-trees materially reduces the stage of high water. But here, as with reservoirs, it is the first rain that falls which wets the leaves and branches and trunks of the trees. When excessive rains come, four and five and six inches, the early rains thoroughly wet and saturate all parts of the forest-trees—trunk, branch and leaf—so that the latter part of the rain will have about the same influence on flood conditions as though the forests were not there. It seems to the writer the importance of quantitative influence of forests has been greatly exaggerated. Enthusiasts even go so far as to claim that could we have our entire country reforested the whole problem of flood preventions would be solved. Such parties should not be called scientists, because the scientist sees in the river flood-plains, as already explained, positive evidence that the river valleys of America have been visited by floods in times past fully as much and probably more than in modern times. This geological evidence is not old simply because it is geological. It deals with the most recent period of geologic time, and links the past with the present. It is little short of folly to teach that destructive floods can be prevented by reforesting the surface of the country, no matter to what extent such reforesting may be carried.

In a measure, forests in a river flood-plain become positively objectionable because they retard the flow of water already in the stream. No sooner does a stream overflow its banks than the forest-trees interfere with the flow of water here, just the same as

they do on the uplands. Anything whatever which retards to any degree the flow of water after it once enters a stream becomes directly a flood producer. There can be no question but that when the water has once overrun the flood-plains every tree, every bush, every blade of grass retards its movements. To whatever extent this is done they are positively objectionable. It is passing strange that so much importance should be placed on this subject at a time so little removed from the days when practically all of the river valleys in America were forested, in view of the fact that all of our history and legends coincide with geological evidence showing conclusively that our rivers overflowed their banks in those days as frequently and to as great an extent as they do now.

LEVEES.

Certain prominent citizens and engineers are enthusiastic over the beneficial effects that may be obtained by the building of levees along river banks in order to prevent flood destruction. It seem to the writer that this method of improvement in general should be handled with great care. In effect, it is virtually the the same as deepening the channel. All rivers while meandering through their flood-plains naturally build levees. Invariably such streams through the greater part of their course have built up the levees from five to ten feet and even twenty feet above the flood-plain farther back from the river. At Lawrence during the flood of 1903 there was one little spot of dry ground on the north side of the river immediately at the river bank. Between this and the bluff to the north in some places the water was as much as ten feet deep, while here the surface was from one to three feet above the water level, showing that the natural river levee was ten or twelve feet higher than the main flood-plain farther towards the bluffs. But with all this natural levee building streams overflow their banks and change their channels. The influence of artificial levees is similar to that of the natural levee. They are first-class for mild floods, but when excessive floods come they must be entirely inadequate, and after the flood-waters break through them they become positively harmful, in that they interfere seriously with the free flow of the water.

One phase of this subject apparently has been overlooked, and it is the most important one, namely, the filling up of the bed of the stream, which in itself is immensely objectionable. Could the Kansas river be leveed five feet in height from Junction City to its mouth, it is practically certain that such a process would increase the tendency of the stream to silt up from the bottom.

As the water in a stream increases in depth there is an increasing variation in the velocity of the water at top and at the bottom. The water near the surface cuts the banks and supplies itself with silt in accordance with its carrying capacity determined by its velocity. A stream twenty feet deep has a larger absolute amount of water near the bottom flowing slowly than the same stream would have when but five feet deep. The silt gathered from near the top gradually works downward and on account of the slow-moving water below silts up the bottom of the river much faster than would be done if the stream were only half as deep. The filling done by one flood simply helps the stream to overflow its banks the more readily during subsequent floods, and therefore becomes a menace.

As just stated, levees undoubtedly are serviceable and satisfactory for mild floods. It is surprising, however, how many engineers, some of them government engineers, overlook the fact that levees must be inordinately high in order to accommodate all the water of great floods. Suppose we should try to levee the Kansas river to hold it within its banks during a flood equal to the one of 1903. At Lawrence the water was more than five miles in width with an average depth of about five feet. The cross-section area, therefore, of the flood-water was so great that levees would have to be built more than ten times as high as is usually mentioned in order to provide a channel which would contain all the water. According to newspaper accounts one of the leading engineering firms of Kansas City made surveys up the Kansas river beyond Lawrence and made a report to a citizens' committee, who employed them, which report in turn was sent to a government engineer. According to these same newspaper accounts both the Kansas City engineers and the government engineer advised building levees to a height only a little greater than that to which the water rose, mind you, on the supposition that it would protect the valley lands from flood-water in the future, omitting entirely to take into consideration the vast amount of water spread out over the valley. They are said to have estimated that such a system of levees could be built for about $14,000 per mile on each side of the river. It cannot be believed that engineers of the reputation of the ones referred to ever would subscribe to such a fallacious doctrine. The influence on the public mind, however, has been wrought and the unscientific landowner situated in the river valley is likely to believe that the newspaper accounts are correct, and that therefore such a system of levees should be built.

It should be noted here also that the tendency of the stream to

meander its channel would be just as effective in times of flood with the flood currents working against the levees as though they were working against a natural bank. The soft materials of the freshly made levees would melt away under such influences with surprising rapidity, and in order that such levees be maintained practically it would become necessary to keep a strong force of men at work along the entire distance leveed throughout each period of high water.

Somewhat similar to levee building is a process of raising the grades of railroads recently indulged in to such an extent in many places along river valleys. If a railroad grade is parallel with the stream, raising the grade will be beneficial to the road. If, however, it is transverse to the direction of the water current, it serves as a dam and only makes a bad matter worse. It is beyond my ability to understand the actions of some railroad engineers in this respect. Here and there we find railroad grades virtually forming dams from bluff to bluff across streams with only a few small openings through which the water can flow. A notable recent example of this is along the Santa Fé railway across the Wakarusa valley south of Lawrence. Since the flood of 1903 this grade was raised from two to five feet. It is almost directly across the river valley. In 1908, I am reliably informed by parties who actually made the measurements, this performed the function of a dam to such an extent that the water was from eighteen to twenty inches higher on the up-stream side than on the lower side. A large amount of money was spent in this movement, only to find that it impeded the flow of the water to such an extent that the last condition, if possible, is worse than the first. What would have happened had the same grade been built five, ten, twenty or a hundred feet higher, provided it was strong enough to withhold the force of the water pressure? It seems plain that it simply would have created a great reservoir on the up-stream side and that ultimately the water-level would have reached the top of the grade just the same as it did before the last improvements. The great mistake was made by not providing suitable outlets for the water to get away.

The engineers evidently thought they did, forgetting apparently that the entire valley in 1903 was necessary for the current. It seems almost madness to assume that in times of a like flood a runway one-tenth or one-twentieth the width of the valley was sufficient to let the water pass.

In a similar manner other river valleys in many places have these great railroad grades crossing them, serving as immense dikes to

impede the current. Almost invariably the openings through them are so few and so entirely inadequate that they cause the water in the river valley to rise much higher than it otherwise would, and therefore such grades become one of the great flood producers.

CHANNEL STRAIGHTENING.

Advocates of channel straightening have many points of fact with them. The fundamental principle underlying this method is the hurrying away of water already in a channel so that it may not be present when the last of the flood-waters arrive. Anything whatever which impedes the water current in a stream tends to produce a flood. In its qualitative influence it becomes a flood producer, because it holds back water already in the channel until new rainfall water may overtake it. Conversely, any influence which will hurry water along and get it out of the way tends to prevent a flood, and therefore should be applied wherever feasible. The universal tendency of streams with flood-plains is to silt up their channels, as already pointed out. This filling in process is greatly increased by driftwood, stumps and other objects becoming lodged, which retard the velocity of the water in the bottom of the stream. Clearing a river channel of stumps and trees and snags, therefore, in a measure increases the velocity of the water. One can hardly believe that intelligent landowners would spend vast sums of money in river improvements to prevent floods and at the same time neglect to provide against such river obstructions. But we find these contradictory actions in many parts of America.

Suppose a drop of rain falling at Junction City occupies four days in traveling to Kansas City, and suppose again that by removing impediments in its pathway its velocity could be increased so that it would make its journey in three days. Certainly at any given point throughout its course it would be out of the way much earlier than should no improvements be made, and, therefore, its influence as a flood producer would be correspondingly lessened. If now we find a stream which has carried its meanderings to such an extent that the length of its course has been doubled, the length of time required for water to travel the course likewise would be doubled, yes, more than doubled, because its actual velocity would be in a measure retarded. Throughout the course of every stream with a flood-plain meandering is more pronounced in some places than in others, and in such places a maximum good could be accomplished by straightening the channel.

In the southeast corner of Bates county, Missouri, the Marais des Cygnes river has excessive windings throughout a stretch of

about twenty-five miles. Under provisions of a state law a drainage district was incorporated and all the land within it taxed to defray the expenses of straightening the channel. A skilled engineer was employed and improvements are now well under way. By building a new channel twenty-three and a half miles in length the present channel, seventy-three miles long, will be abandoned. It is estimated that it now requires water three and a half days to travel this seventy-three miles, while but eight hours will be required to travel the twenty-three and a half miles. This shortening of time is much greater than shortening of distance, because, with no curves to encounter, the water will meet with less friction. Again, the twenty-three and a half miles will have the same absolute fall as the seventy-three miles, changing the fall per mile from eight inches to about twenty-six inches, which of itself would almost double the velocity of the water.

Suppose now we have a flood-time in the upper Marais des Cygnes river and that a given stage of flood is reached at the upper part of the straight channel. Within eight hours this water will have traversed the twenty-three and a half miles and be entirely out of the way of succeeding portions of the flood, while under previous conditions it would require three and one-half days to pass the lower point of the new channel, and therefore more than two-thirds of the early flood-water would be retained and added to the later flood-water. Certainly such an improvement will have a very strong tendency in the right direction. Could the Marais des Cygnes river have its channel straightened from the vicinity of Quenemo, in eastern Osage county, Kansas, to its mouth, below Jefferson City, it seems probable that the floods would be greatly reduced.

One of the phases of this subject that should be emphasized is the possibility of using the waste energy of the water current to help in cutting new channels. There is no more necessity of using man power and steam power to do all the work than there is for using like power to turn the turbine wheels at a water-power plant. An engineer who fully understands river principles can devise means for applying the current energy.

DAMS.

Since the flood of 1903 much agitation regarding flood causes and flood preventions in one way and another has been connected with dams across streams. Here again it seems to the writer facts are not understood.

The influence of a dam across a stream during a mild flood cer-

tainly is in the direction of causing the river to break over its banks up stream from the dam. This influence, however, is not so entirely an unmitigated evil as is an ordinary obstruction in a river channel. A tree or bridge pier or snag checks the velocity of water and in no degree works a recompense for it, so that its influence is entirely bad. A dam across a water stream checks the velocity of water, but in turn necessarily in a measure compensates for it by causing the water to flow with greater velocity as it passes the dam. Observations and measurements universally show that when water begins rising in a stream it rises faster below the dam than it does above, so that when a stream becomes sufficiently high the presence of the dam cannot be told from the appearance of the surface of the water.

Let us suppose that we have a dam five feet high. At low stages of water the water-level above the dam will be five feet above the water-level below. As a flood approaches this difference in level begins diminishing—first to four and one-half, then four feet, then three and one-half, etc. A little thought will show why this is so. Let us assume that we have a rise of ten feet above the dam, so that a volume of water ten feet in depth will flow over the dam. Now, every one knows that the water at and near the surface flows very much faster than water near the bottom of the stream. The farther the surface is removed, therefore, from the top of the dam as the flood rises the less influence the dam will have on this rapidly flowing water, which constitutes the main run-off of the stream. During low stages the dam, therefore, produces its maximum effect, which effect is gradually decreasing in percentage proportion as the water rises.

In confirmation of the above theoretical consideration it should be added that a careful investigation of the Kansas river valley immediately after the flood of 1903 failed to reveal any material difference in damages produced along the river valley above and below the dam at Lawrence. I had eight assistants working under me examining the river valley from its mouth westward to Junction City. These were young men not one of whom was a citizen of Douglas county. One of the charges I gave them was to look carefully into this question and determine if possible whether or not the dam at Lawrence produced any appreciable effect in the volume of damage done by the flood below the dam and above the dam. The unanimous statement was that, so far as they could determine by careful observations, flood damages were just as great below as above.

In times of mild floods, however, dams certainly do produce bad effects. They cause the water first to break over the river banks above the dam, which in turn is liable to set up new channels, and to flood certain areas which otherwise would not be disturbed.

SPILLWAYS.

It has been suggested that where dams are built spillways should be provided around an end of the dam so that during mild floods an excessive amount of water could flow past the dam without overflowing the banks above. This, under certain circumstances, would be a move in the right direction. Its value would be made *nil*, however, provided the channel of the stream below the dam was not sufficiently wide to carry away the water as fast as it passed over the dam and spillway combined. The production of a spillway beyond this point would be an unnecessary waste of money. This question of dams and spillways is here introduced because again the public press, from time to time since the flood of 1903, has been agitating the subject, and great dissatisfaction and unrest have been worked up with the masses of people living in the river valleys in eastern Kansas and other parts of America. According to press reports a government engineer recently has passed up and down the Kansas river valley and its tributaries, counting the dams across the various streams, and giving utterance to statements in effect that such dams must be removed, after which damage from flood will be a thing of the past. I wish to call attention to the well-known fact, as before stated, that these same streams overflowed their valleys practically to as great an extent before such dams were built as they do now. We have abundant historic evidence of this covering the past fifty years, and we have positive geologic evidence of this written in the flood-plains of the streams, as already explained. It should be remembered, therefore, that such dams may produce bad influences during mild floods, but that these bad influences decrease as the floods increase in volume, so that when the flood reaches the proportions of those of 1903 practically the dams' influences are almost *nil*.

All too often it happens that attempts at river improvements are made in the wrong direction. For a sad example of this, I need only refer to actions of citizens at Pine Bluff, Ark., in their attempt to protect property from river destruction during the flood of the Arkansas river only a few weeks ago. Here is a town situated on the convex side of a bold ox-bow curve in the river. At flood-time the current was constantly striking against the bank so as to increase the crookedness of the channel. Opposite this part, along the con-

cave side of the curve, where the current already was so weak it was depositing parts of its load, a citizen's committee began cutting down the bank and throwing the dirt into the water in an attempt to entice the strong current away from the opposite bank. What they did in reality was to add to nature's methods by which the river was first made crooked, and, therefore, so far as they had any influence on the stream they made it wear away with increased energy the very bank they hoped to protect.

A most important consideration which should be made prominent is the futility of attempting great river improvements in restricted areas with a hope of accomplishing much good therefrom. A stream large enough to do great damage must necessarily drain a sufficiently large area to make mere local improvements of but little value. We must expand our conceptions of the magnitude of nature's processes and modify our efforts accordingly. For a stream as big as the Kansas river, or Missouri river, with a flood-plain from three to five miles wide, what a great disappointment awaits those who now have faith in mere local improvements. There should be a coöperation of all interested parties for a distance of at least a hundred miles up and down the valley, and two hundred miles would be much better. Great floods are not mere local affairs, and little can be expected from mere local treatment.

On the other hand, river improvements are immensely expensive. No class of citizens is justified in spending vast sums of money to save property unless reasonable returns are to a degree insured. While the American Indians roamed over our vast prairies and held a valuation on land of less than one cent an acre, no such land would bear taxation sufficient even for building respectable fords across the streams, much less for building bridges, while as for improvements to guard against flood devastation it was entirely unthinkable. But when a great city is built and land becomes worth a thousand dollars a front foot, it would almost stand taxation to encase the stream in polished marble.

In general land values in America are now intermediate between the two extremes just named. The time has come when we should begin to make improvements, but values in general are yet too low to admit of very great ones. The intelligent thing to do, therefore, is to begin work in the right direction, strictly in accord with the laws of nature, and on sufficiently broad lines so that ultimately our accomplishments will be commensurate with our efforts. We should harness the water currents and compel them to turn their great surplus energies into our hands for us to direct their expen-

ditures in a manner that will accomplish the desired ends. If the energy of a water current builds great crooks and curves in a channel when allowed to run wild, then the same energy may be made to straighten the same channel if properly applied. If a stream is capable of doing sufficient work to transport vast amounts of material necessary to build up its flood-plain scores of feet in thickness and miles in width, then the same stream may be made to keep its own channel free and clear of obstructions just as soon as the mind of man becomes capable of directing the work. We are not here dealing with the changeable whims of an individual, but with the immutable and unchangeable laws of inanimate matter. Let us all hope that in the near future our minds may be opened up to a full comprehension of such laws and how to apply them to our good, and that our hearts may be expanded so that we may all work in perfect harmony in accomplishing these great ends.